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Correlation between morphology, behaviour and habitat - bivalve burrowing in simulation and robotics

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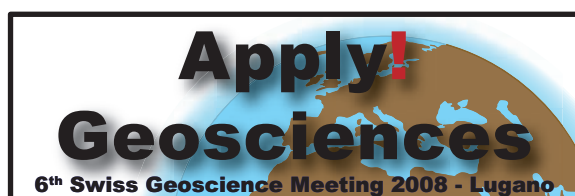
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Table of contents

Organisation	3
Abstracts	
0. Plenary Session	4
1. Structural Geology and Tectonics (Open Session)	10
2. Mineralogy-Petrology-Geochemistry (Open Session)	72
3. Palaeontology (Open Session)	114
4. Meteorology and Climatology (open session)	136
5. Quaternary Research (Open Session)	146
6. Apply! Snow, Ice and Permafrost Science + Geomorphology (Open Session)	172
7. Geofluids and related mineralization: From shallow to deep	210
8. Building Stones - Application, suitability, research	230
9. Natural Hazards and Risks	240
10. Anthropogenic impacts on hydrological regime	272
11. Who Cares About Water? - Social Aspects of Water + Environmental Challenges of Border Regions	284
12. Data acquisition, Geo-processing, GIS, digital mapping and 3D visualisation	296
13. Global change – Lessons from the geological past	328
14. Deep Earth – From Crust to Core: A Tribute to Peter A. Ziegler	340
Author Index	348

3. Palaeontology (Open Session)

Damien Becker

Swiss Palaeontological Society (SPS)

Kommission des Schweizerischen Paläontologischen Abhandlungen (KSPA)

- 3.1 Ayer J., Comment G., Adatte T., Badertscher C., Boll S., Fürsich F.T., Gretz M., Hug W.A., Marty D. : Sedimentology and palaeocology of the Banné Member (Late Jurassic, Kimmeridgian): new data from excavations along the Transjurane highway (Canton Jura, Switzerland)
- 3.2 Baumgartner-Mora C., Baumgartner P.O., Buchs D. Bandini A., Flores K.: Palaeocene to Oligocene Foraminifera from the Azuero Peninsula (Panama): The timing of seamount formation, accretion and forearc overlap, along the Mid-American Margin
- 3.3 Becker D., Scherler L., Tütken T., Aubry D., Detrey J. : The Late Pleistocene mammalian fauna from Ajoie (Northwestern Switzerland): stratigraphy, taphonomy, palaeoecology
- 3.4 Berger J.-P., Reynard E., Constandache M., Dumas J., Felber M., Häuselmann P., Jeannin P.-Y., Martin S., Regolini G., Scapozza C., Schneider H.: Inventory of geotopes of national significance: the paleontological record
- 3.5 Cavin L., Meister C., Piuz A., Boudad L. : Fossil assemblages from the early Late Cretaceous of southeast Morocco
- 3.6 Germann D., Schatz W., Hadorn M., Fischer A., Eggenberger H.P. : Correlation between morphology, behaviour and habitat – bivalve burrowing in simulation and robotics
- 3.7 Goudemand N., Orchard M., Bucher H., Brayard A., Brühwiler T., Galfetti T., Hermann E., Hochuli P.A., Ware D.: Smithian-Spathian boundary: the biggest crisis in Triassic conodont history
- 3.8 Lavoyer T. & Berger J.-P.: New data on the Bouwixiller Formation (Eocene, Lutetian)
- 3.9 Marty D., Paratte G., Lovis C., Jacquemet M., Hug W.A., Iberg A., Oriet A., Denier C., Mihajlovic D. : Methodology of systematic excavation and documentation of dinosaur tracksites along the Transjurane highway (Canton Jura, NW Switzerland)
- 3.10 Mennecart B., Zulliger L., Scherler L., Becker D., Berger J.-P.: A new Aquitanian fauna in the Jura Molasse (Sur le Mont, Tavannes, Northwestern Switzerland)
- 3.11 Renesto S., Lombardo C., Stockar R. : New excavations in the Cassina levels (Monte San Giorgio, Middle Triassic) preliminary reports
- 3.12 Reynard E., Berger J.-P., Constandache M., Dumas J., Felber M., Häuselmann P., Jeannin P.-Y., Martin S., Regolini G., Scapozza C., Schneider H. : The revision of the inventory of geotopes of national significance
- 3.13 Scherler L., Mennecart B., Becker D., Berger J.-P.: Tapiridae (Perissodactyla, Mammalia) of the Swiss Molasse Basin during the Oligo-Miocene transition: taxonomical study and preliminary results
- 3.14 Schweizer M., Thierstein H., Schulz H., Darling K.: How similar are morphological and genetic diversities recognizable on a typical plankton filter?
- 3.15 Yazdi M. & Mannani M.: Two Late Triassic biostroms levels as key beds for controlling sea level changes in Central Iran

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3.6

Correlation between morphology, behaviour and habitat – bivalve burrowing in simulation and robotics

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Bivalves show a large diversity of shell shapes and sculptures during their long history of evolutionary adaptations to different modes of life. The comparatively dense fossil record of bivalves, the well-defined morphological space and the quite complete picture of bivalvian phylogeny offer basis for an analysis of general evolutionary processes. However, while the fossil record conveys information about the shape and the habitat of bivalves, the interpretation of the functional morphology, locomotion and changes in shell shape is generally vague, as fossils represent only discrete states in the morphological space and suffer from the preservational bias. Thus, the purpose of this project is to extend the knowledge about the evolution of bivalves and their adaptations to burrowing using both a computer simulation and a burrowing robot. The simulation will cover the dynamics of burrowing as well as the evolution in morphology and behaviour, reconstructing a trajectory in the morphological space and analysing the processes inducing these state-shifts.

There already exist mathematical models of sea shells (e.g. Raup & Michelson 1965), models of granular media (e.g. van Wachem & Almstedt 2003), burrowing robots and simulations of artificial evolution, but they have never been combined. Our simulation consists of (i) models of recent, fossil and artificial bivalve morphospecies, (ii) a model of a granular medium including the physical interactions with the shell, (iii) an implementation of the burrowing sequence (cf. Trueman 1966) and (iv) an artificial evolutionary system. The artificial evolution may change parameters controlling the behaviour or the morphology of the bivalves. Using a computer simulation allows an efficient and systematic analysis of the burrowing efficiency by changing just a single parameter at a time.

The virtual shell models are converted into physical objects using a 3D-printer (Fig. 1). As a starting point for the physical experiments, finally leading to a self-sufficient burrowing robot, we will attach the shell to two rods simulating the rocking locomotion of the bivalve during the burrowing process (cf. Stanley 1975). In further steps, the opening and closing of the valves and finally an artificial foot probing into the sediment will be added to complete the robot. The data provided by the robot is used to calibrate the simulation and to assess the coherence of the model and the physical reality. After testing the biological significance of the simulation, we will explore the functional correlations between the shell shapes and sculptures, the burrowing behaviour and the sediment type.

As shown in earlier examples (Hadorn et al. 2004), a close collaboration between palaeontology and evolutionary computation/robotics can return profit for both scientific fields. A possible application of this research may be a tool for palaeontologists to link shell forms and the mode of life of fossil bivalves in a more sophisticated way. The simulation can be used to perform experiments with evolution, to identify functional constraints, to find explanations for aberrant and extinct shell forms and even to create and test shell forms that have never existed. By investigating the functionality not only of recent but also of fossil shells, the field of bionics could be remarkably extended. In industry, the robot might serve as a prototype for autonomous burrowing robots or removable and fixed anchorage of man-made structures in soft sediments.

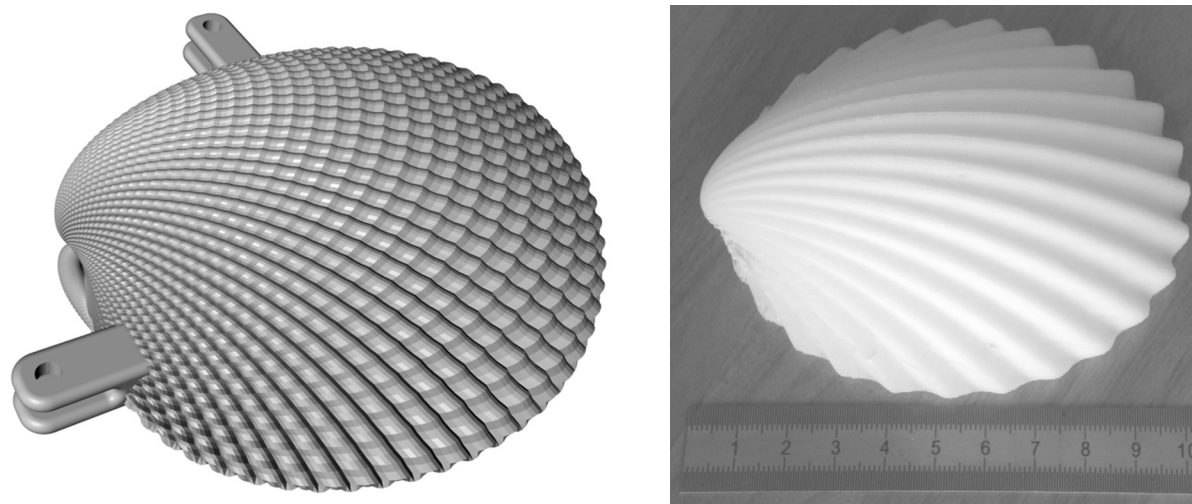


Figure 1. Left: An artificial shell generated by the simulation software with added sockets for the rods. Right: Photo of a valve printed by the 3D-printer (scale in centimetres).

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3.7

Smithian-Spathian boundary: the biggest crisis in Triassic conodont history

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Ongoing work in California, S-China, Tibet, Pakistan and Oman has led to a refined biochronologic subdivision of the late Early Triassic and allows reconstructing a high resolution diversity time series, partly constrained by new U-Pb ages from S-China (Galfetti et al. 2007a).

Conodonts crossed the PTB without major changes (Orchard 2007). In the Early Triassic the first major conodont faunal turnover occurred during the late Griesbachian - early Dienerian, with the disappearance of Anchignathodontids (*Hindeodus*-*Isarcicella* group), which were replaced by the emergent *Neospathodus* and *Borinella*? species.

In the earliest Smithian, conodonts experienced a dramatic radiation, which ended in a major extinction during the late Smithian. This extinction was the most severe of the entire Triassic in terms of generic diversity and multi-element apparatuses. In the early Spathian conodonts radiated again explosively and gradually declined during late Spathian times.

These global diversity patterns coincide with large perturbations of the global carbon cycle (Brühwiler et al. 2007; Galfetti et al. 2007b, Payne et al. 2004). As indicated by changes in the latitudinal gradient of generic richness of ammonoids, the boreal palynological record, and a prominent positive $\delta^{13}\text{C}$ -isotope shift, the late Smithian - early Spathian boundary interval is marked by a severe climatic change.